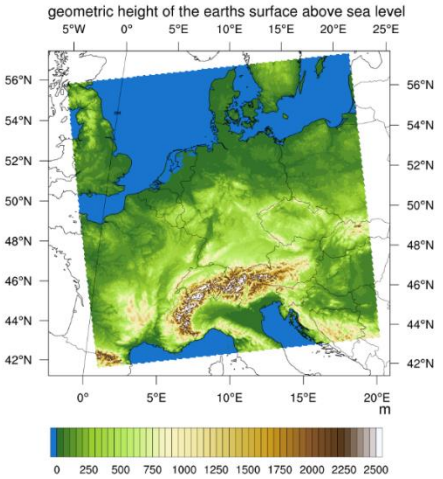
Sensitivity of simulated convective precipitation to model settings using ICON-CLM in Central Europe

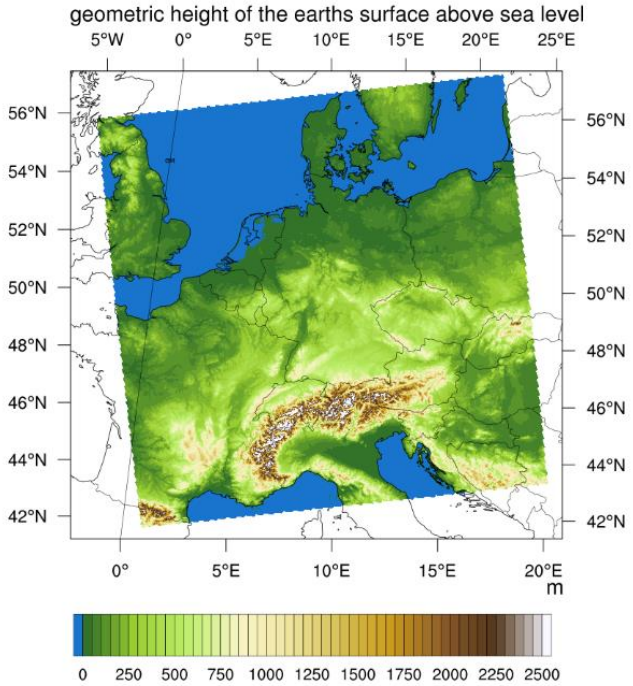
Christopher Purr, Susanne Brienen*,
S. Morak-Bozzo, S. Singh, V. Maurer, C. Steger
(Deutscher Wetterdienst)

and the whole **CECPI-Ger team**



CECPI-Ger initiative (WG CRCS)

- **Goal**: find a configuration for ICON-CLM at convection permitting scale over Central Europe
- **Model:** ICON-CLM v2024.07
- **Reference configuration**: NWP settings
- **Forcing**: ERA5 + ICON-CLM 12km configuration
- **Time period**: years 2002-2003
- **Sensitivity simulations** in parameterizations:
  - convection
  - microphysics and cloud scheme
  - turbulence
  - SSO
  - numerical diffusion



CORDEX-CMIP6 dowscaling from UDAG project

GCM CMIP6

- **MPI-ESM1-2-HR**
- **EC-Earth3-Veg**
- **MIROC6**
- CNRM-ESM2-1

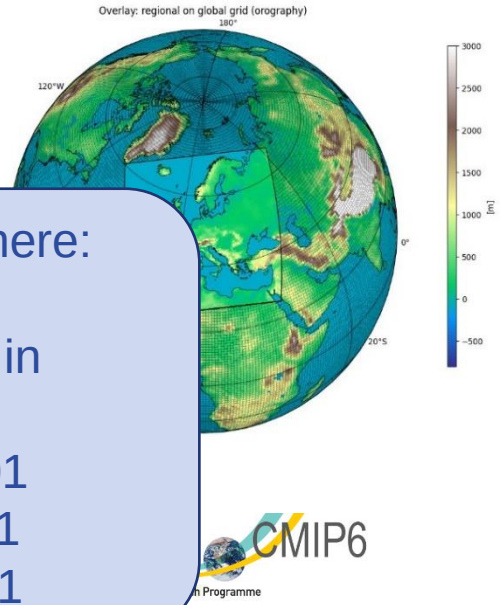
scenario

- **SSP1-2.6**
- SSP2-4.5
- **SSP3-7.0**
- SSP5-8.5

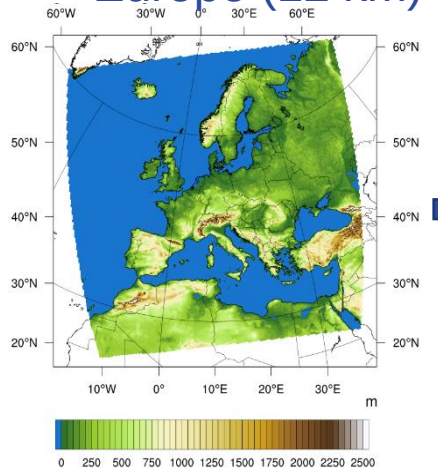
analyzed here:

historicals in 3km:
IMHISTH01
IEHISTH01
IRHISTH01

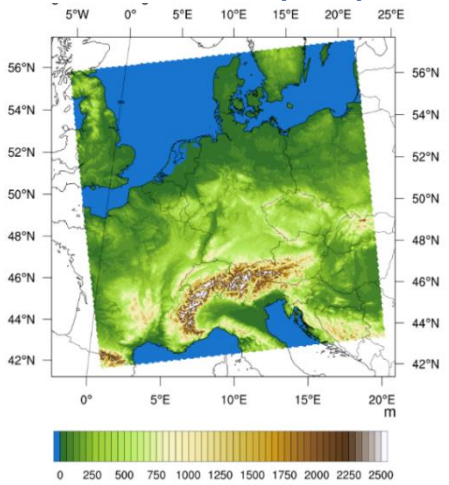
Global (80 km)



Europe (12 km)



Central Europe (3 km)



ICON

bold: also 3km

2 more GCM + COSMO-CLM simulations from partners in CLM-Community

Analysis of hourly precipitation statistics

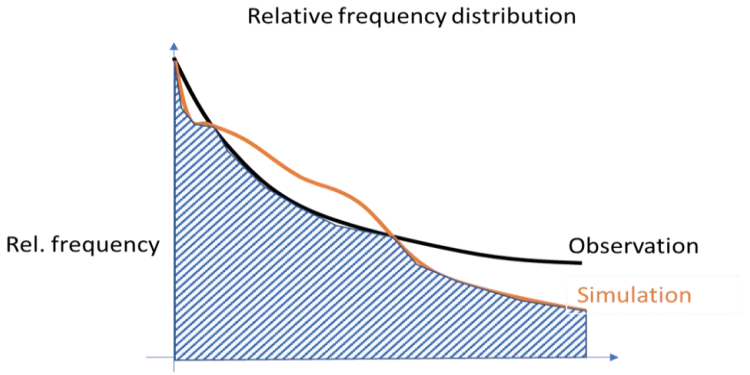
- Reference data sets:
  - **RADKLIM climatology** (Winterrath et al., 2018):
    radar measurements corrected with station observations (v2017.002)
    1x1km grid, Germany, 2001-2022, hourly
  - **Station measurements**, point observations, hourly, 210 stations
  - diurnal cycle: additional daily average from **HYRAS** (gridded station measurements, 1x1km grid, Germany, 1931-2025, Rauthe et al., 2013)

Rauthe, M., H. Steiner, U. Riediger, A. Mazurkiewiczand A. Gratzki, 2013: A Central European precipitation climatology -Part I: Generation and validation of a high-resolution gridded daily dataset (HYRAS), Meteorol. Z., Vol. 22(3), p 235-256, DOI:10.1127/0941-2948/2013/0436.

Winterrath, T., C. Brendel, M. Haferio, T. Junghänel, A. Klameth, K. Lengfeld, E. Walawender, E. Weigl and A. Becker (2018): RADKLIM Version 2017.002: Reprocessed gauge-adjusted radar data, one-hour precipitation sums (RW) DOI: 10.5676/DWD/RADKLIM_RW_V2017.002 (data access: https://opendata.dwd.de/climate_environment/CDC/help/landing_pages/doi_landingpage_RADKLIM_RW_V2017.002-en.html)

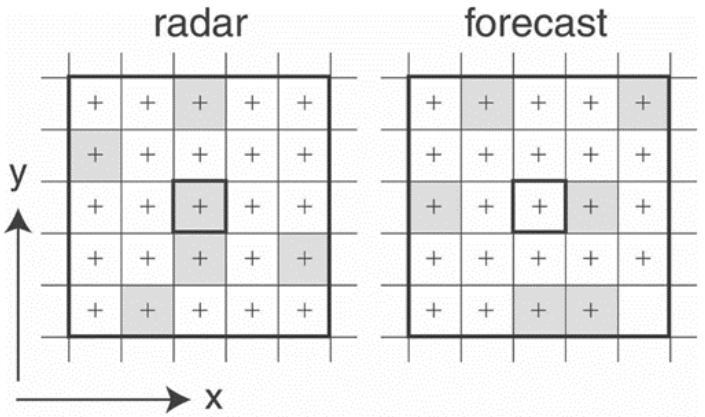
Analysis of hourly precipitation statistics

- **statistics**:
  - **99th, 99.9th, 99.99th percentile**
  - **Perkins Skill Score** (Perkins et al, 2007) comparison of PDFs
  - **Fraction Skill Score** (Roberts and Lean, 2008) comparison of grid point fractions with precipitation
  - **Diurnal Cycle**



$$P_{score} = \sum_{i=1}^{n} \min(obs_i, sim_i)$$

- Best score: 1
- Worst score: 0



Perkins, S. E., Pitman, A. J., Holbrook, N. J., and McAneney, J.: Evaluation of the AR4 Climate Models' Simulated Daily Maximum Temperature, Minimum Temperature, and Precipitation over Australia Using Probability Density Functions, J. Climate, 20, 4356–4376, 2007.

Roberts, N. M., and H. W. Lean, 2008: Scale-Selective Verification of Rainfall Accumulations from High-Resolution Forecasts of Convective Events. Mon. Wea. Rev., 136, 78–97, https://doi.org/10.1175/2007MWR2123.1..

Sensitive parameters for hourly precipitation

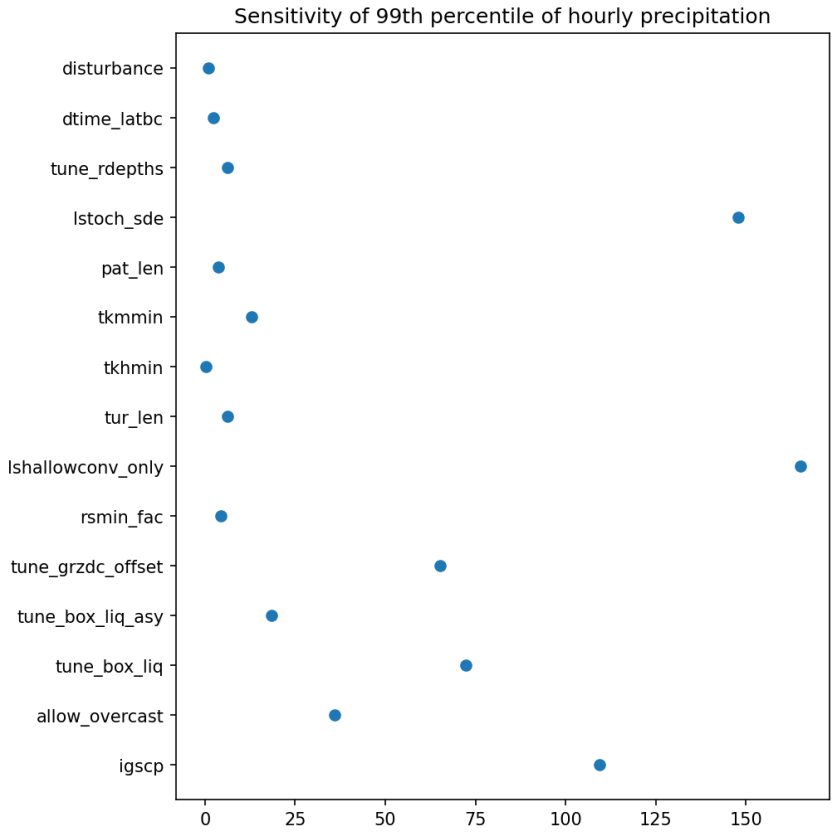
Simulation ID	Short name	Namelist parameter	Description
CEI100c	REF	-	Reference (NWP config)
CEI104c	lsco	lshallowconv_only	Use shallow convection scheme instead of grayzone tuning
CEI105c	ao	allow_overcast	Tuning the dependence of liquid cloud cover on relative humidity
CEI106c	tbl	tune_box_liq	Box width for liquid cloud diagnostic in cloud cover scheme
CEI107c	tbla	tune_box_liq_asy	Asymmetry factor for liquid cloud cover diagnostic
CEI118c	igscp	inwp_gscp	Use 2-moment microphysics
CEI119c	lssde	lstoch_sde	Use stochastic shallow convection
CEI166c	tgo	tune_grzdc_offset	Scaling factor for CAPE closure in grayzone convection to reduce activity and suppress drizzle
CEI195c / 193c	FINAL	LiMMo tuning	Final configuration

[Convection]
[Cloud scheme]
[Microphysics]

intrinsic variability: disturbance simulation / grey shading

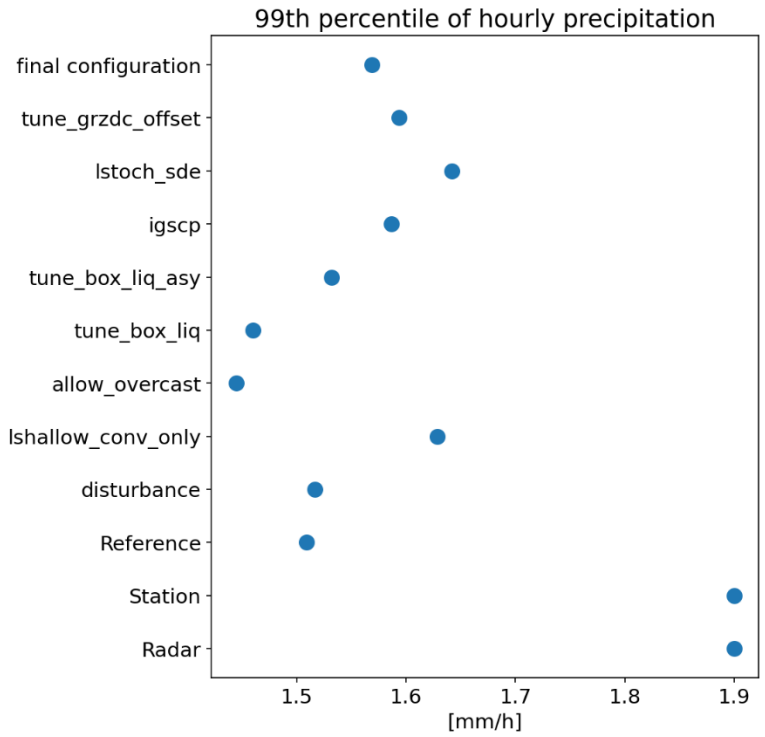
Sensitivity of extreme precipitation to model parameters

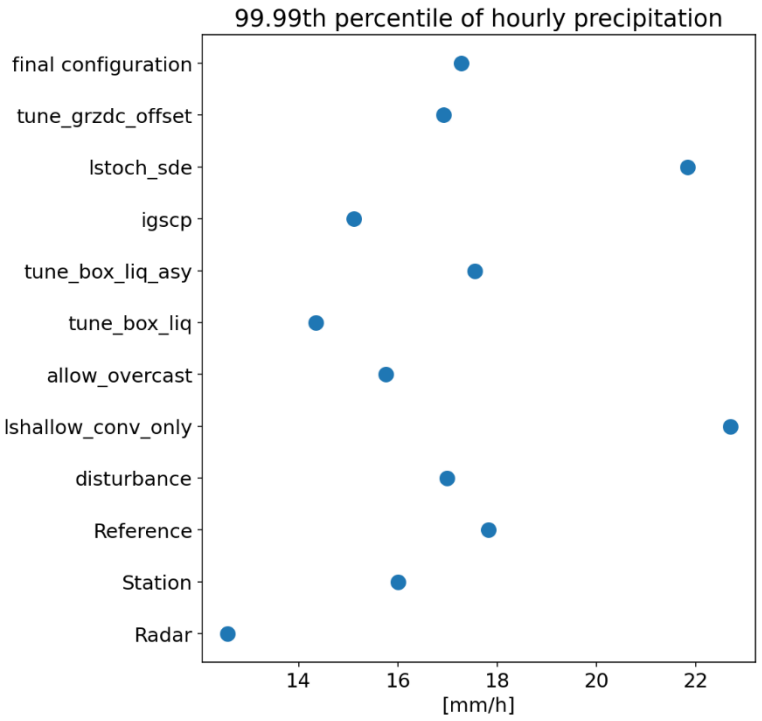
- Definition: $Sens_{P99} = \frac{|P99_{Test} - P99_{Reference}|}{|P99_{Disturbance} - P99_{Reference}|}$
- Sensitive model settings:
  - Shallow convection only (no gray-zone tuning)
  - Stochastic onset of shallow convection
  - Two-moment microphysics
- Sensitive parameters are similar for all statistics (percentiles, Perkin‘s skill score, Fraction Skill Score)
  - 99th percentile shown as example



Quality of extreme precipitation in test simulations

- General underestimation of 99th percentile and overestimation of 99.99th percentile
- Both values improved by tune_grzdc_offset and igscp
- Shallow_conv_only and lstoch_sde make 99.99th percentile worse

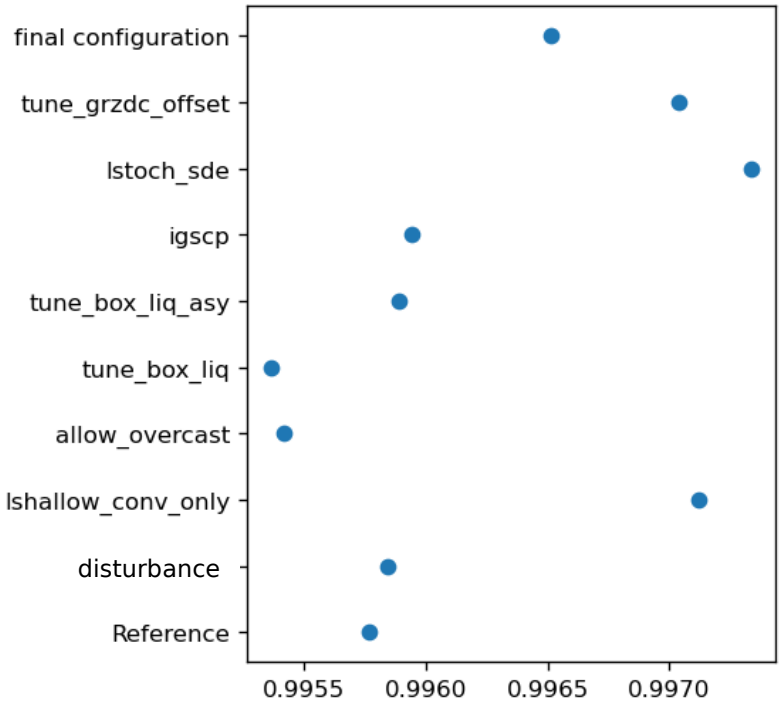




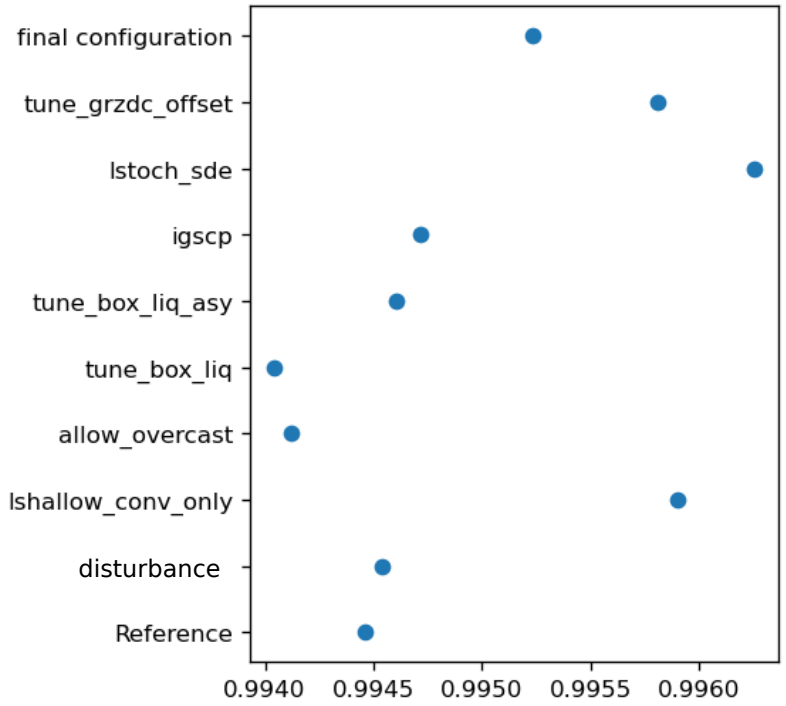
Perkin‘s skill scrore

- frequency distribution of hourly precipitation is best reproduced in lstoch_sde, followed by shallow_conv_only and tune_grzdc_offset
- two-moment scheme (igscp) increases the PSS only marginally
- changing the observations does not change the relative improvements of the test simulations

Score w.r.t. radar data

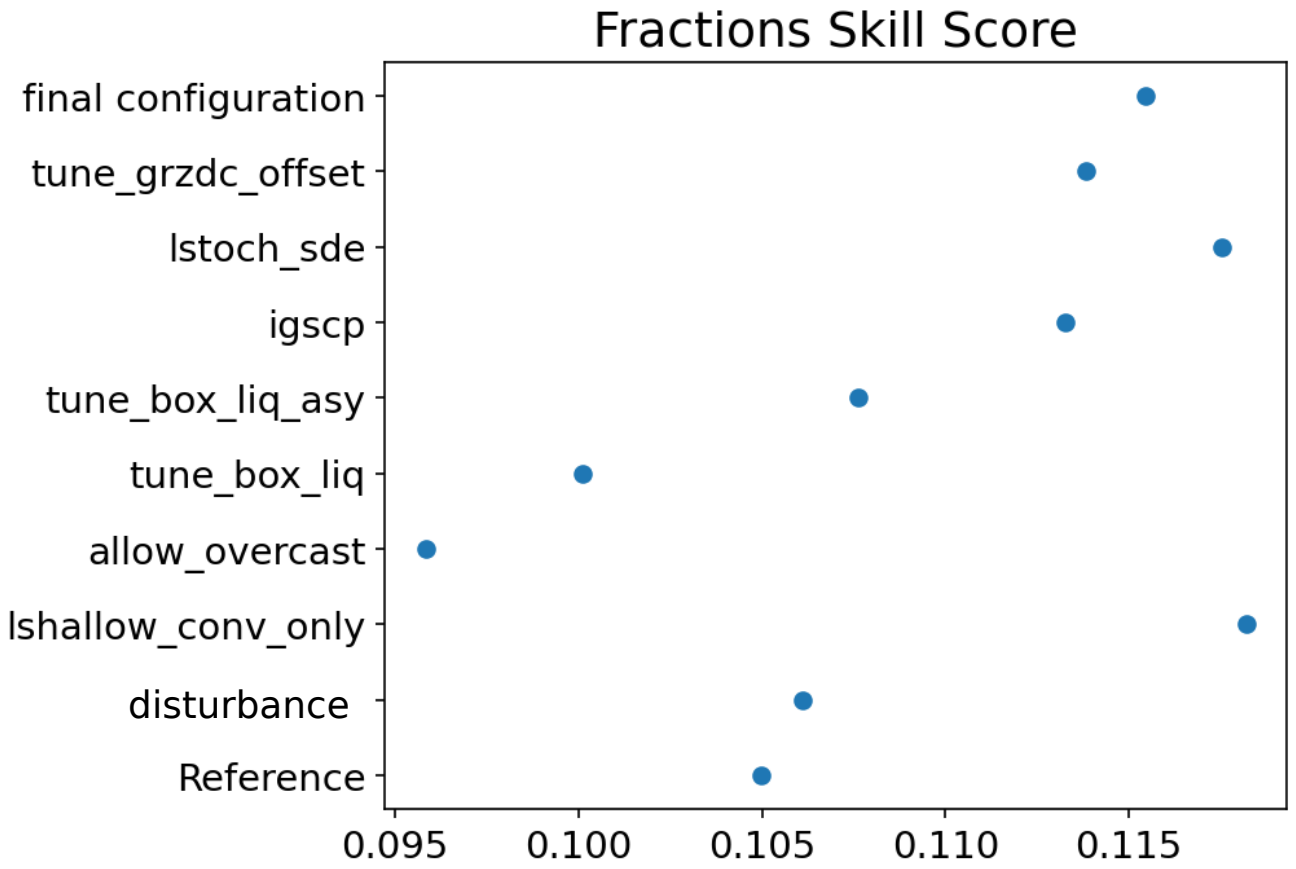


Score w.r.t. station data



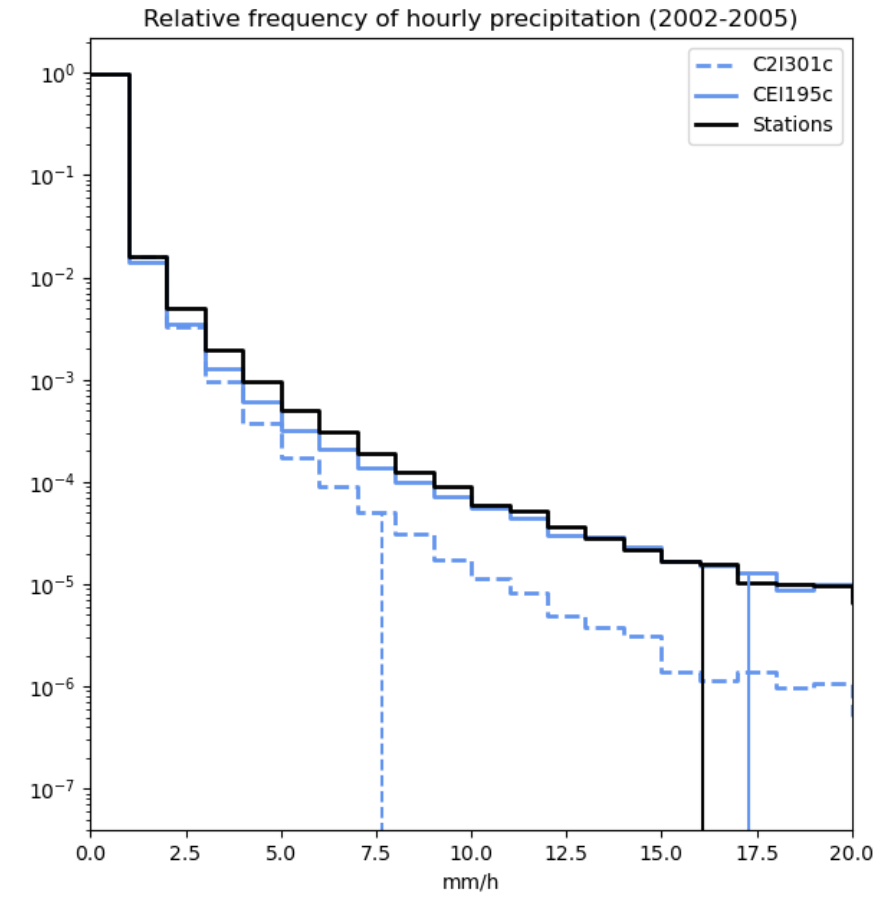
Fractions skill score

- score increases in majority of test simulations compared to the reference simulation
- best simulations are lshallow_conv_only and lstoch_sde



Quality of extreme precipitation compared to 12km simulation

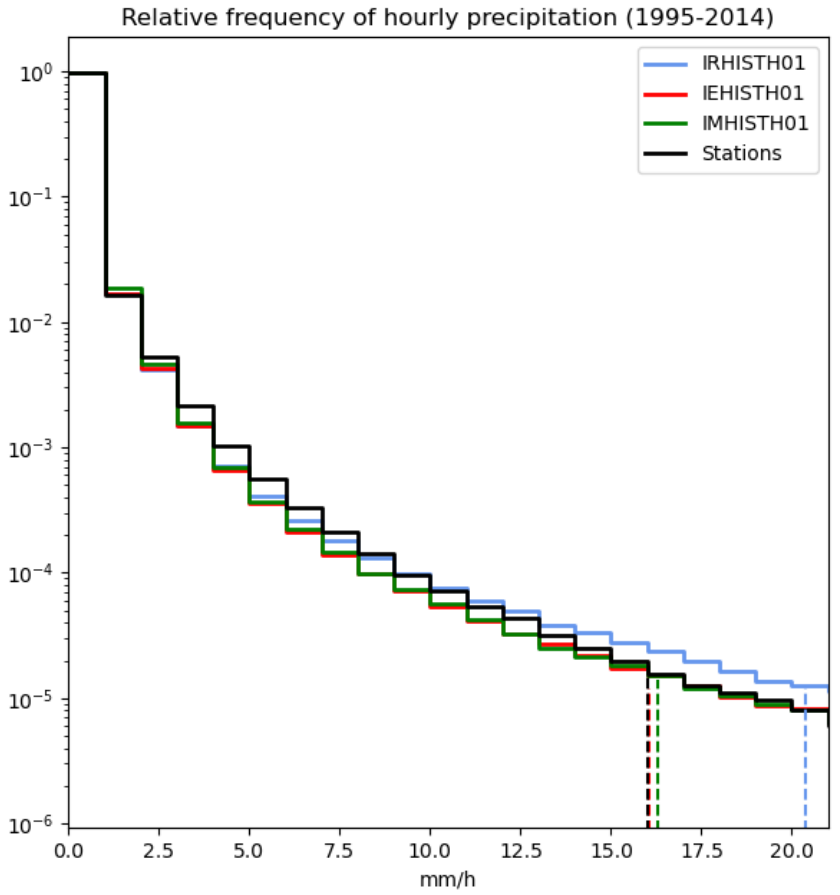
- Extreme precipitation better simulated in convection-permitting setup



Dashed vertical lines denote 99.99th percentile

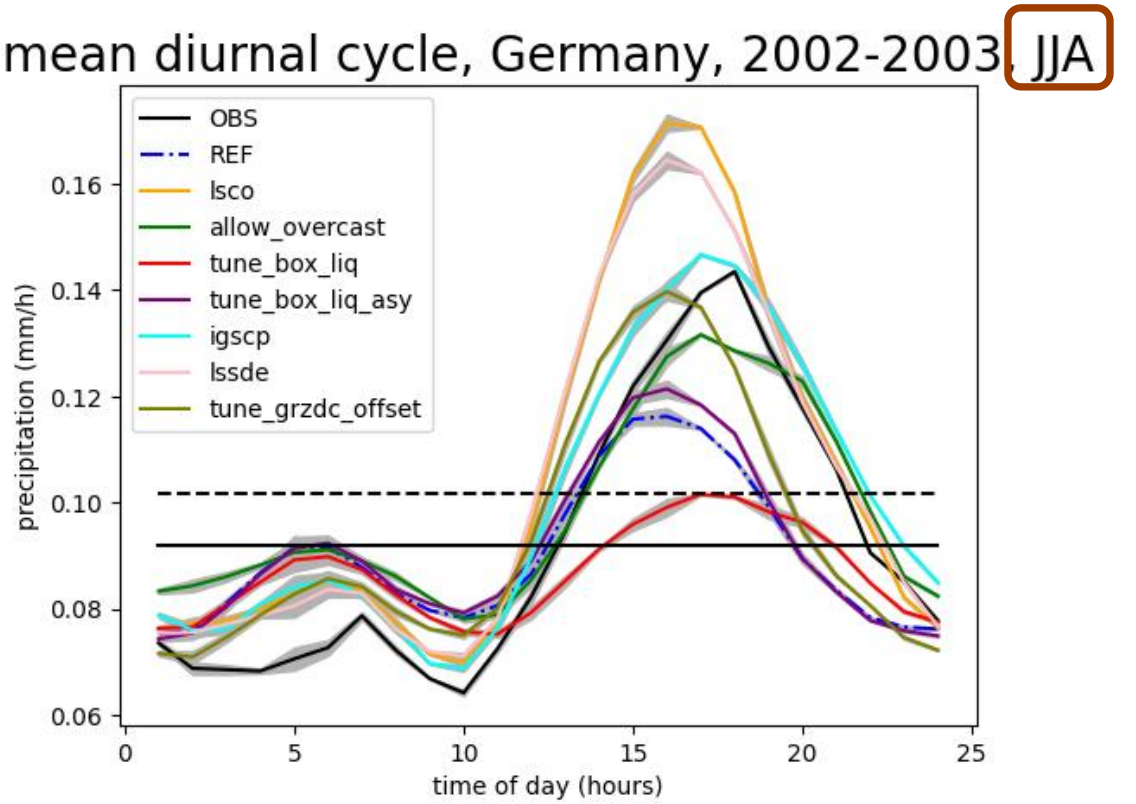
Quality of extreme precipitation in historical simulations

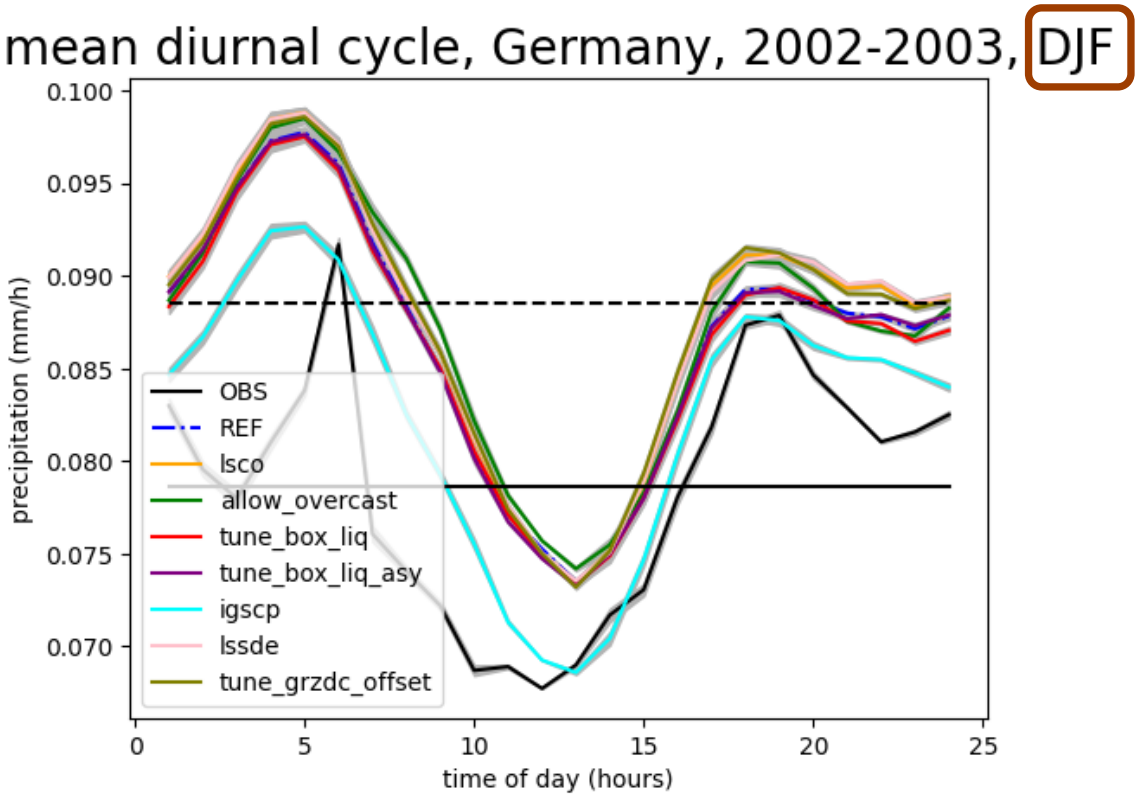
- Fequency of extreme precipitation well simulated by MPI-ESM and EC-Earth driven simulation
- MIROC driven simulation overestimates extreme precipitation



Dashed vertical lines denote 99.99th percentile

diurnal cycle: sensitivites

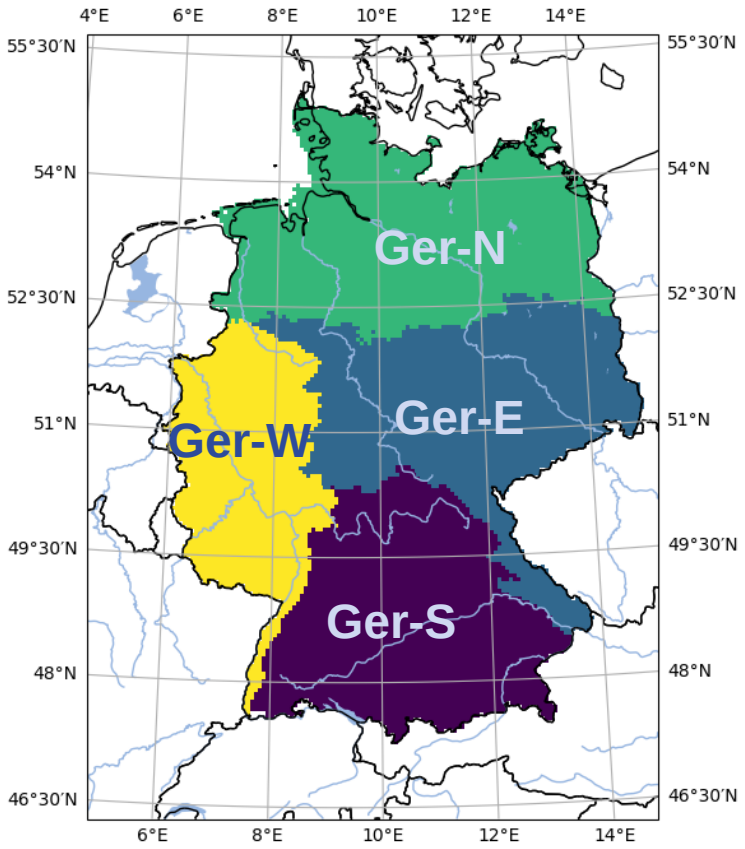




OBS:

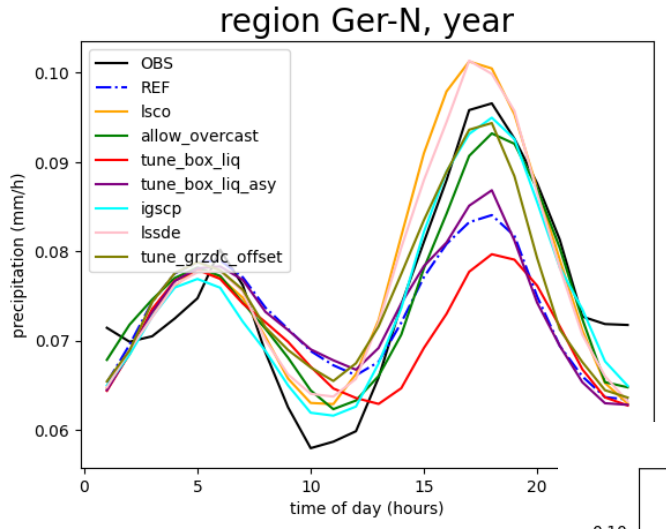
- continuous: RADKLIM cycle + daily mean
- dashed: HYRAS daily mean

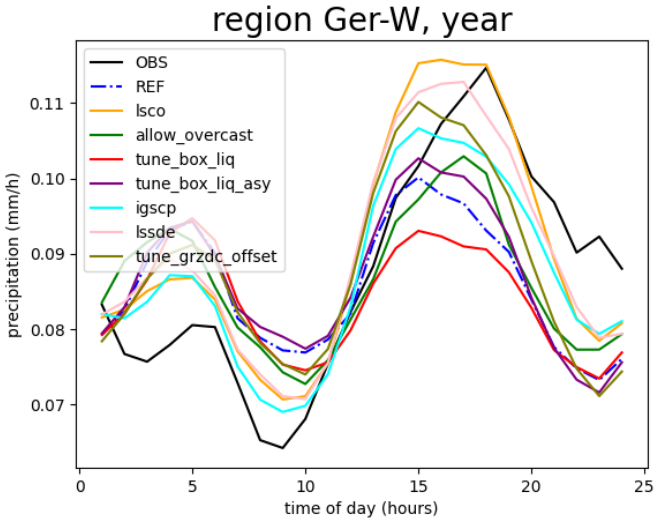
4 regions in Germany (based on „natural areas“)

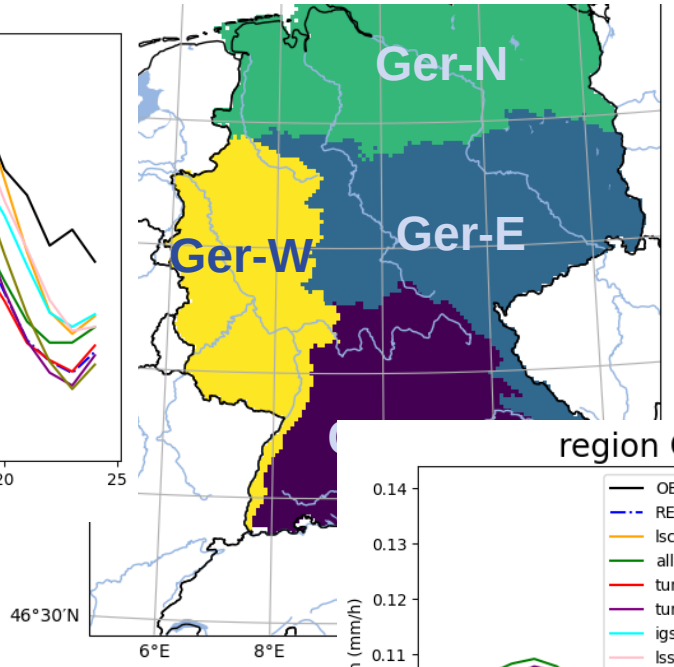


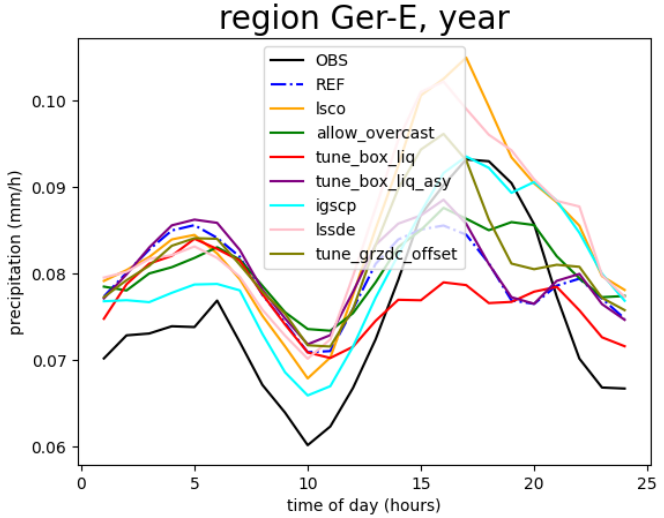
Ger-N: Norddeutsches Tiefland, Nordwestdeutsches Tiefland
Ger-W: Westdeutsche Tieflandsbucht, Linksrheinische Mittelgebirge, Rechtsrheinische Mittelgebirge, Oberrheinisches Tiefland
Ger-E: Zentrale Mittelgebirge und Harz, Ostdeutsche Becken und Huegel, Oestliche Mittelgebirge
Ger-S: Suedwestdeutsche Mittelgebirge, Alpen, Alpenvorland

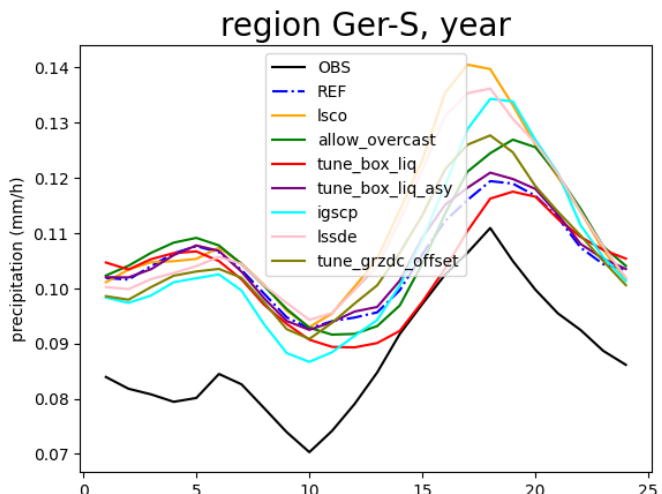
regional differences





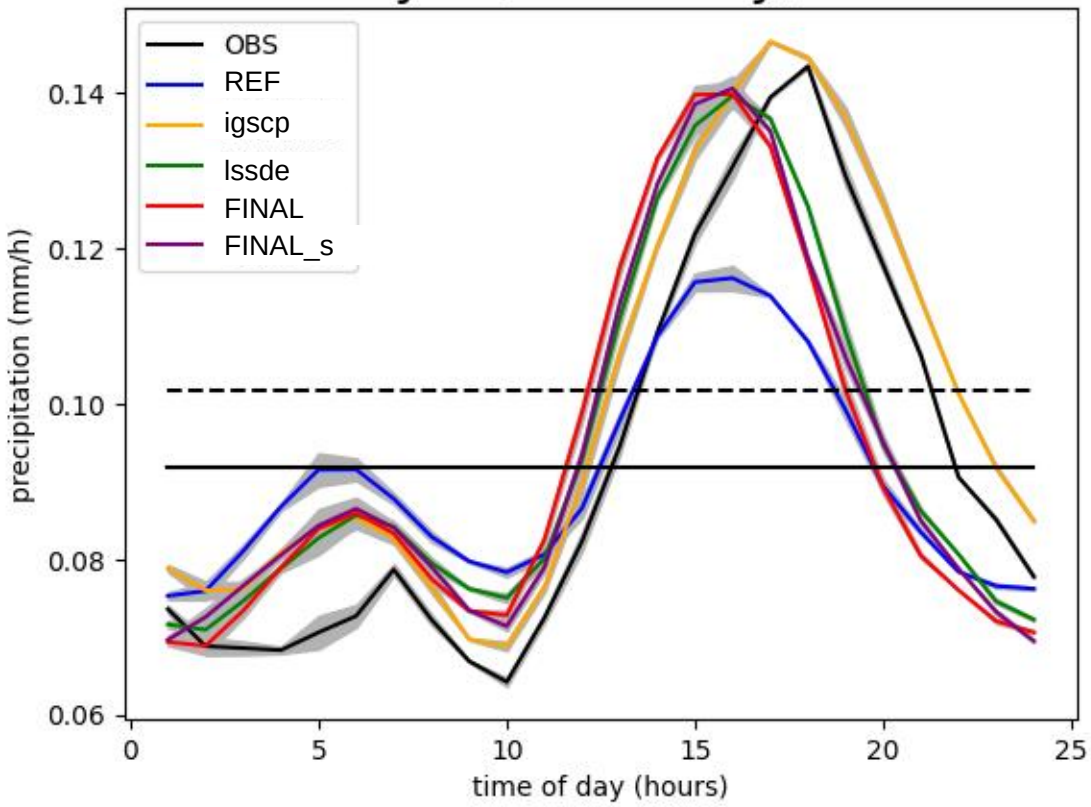




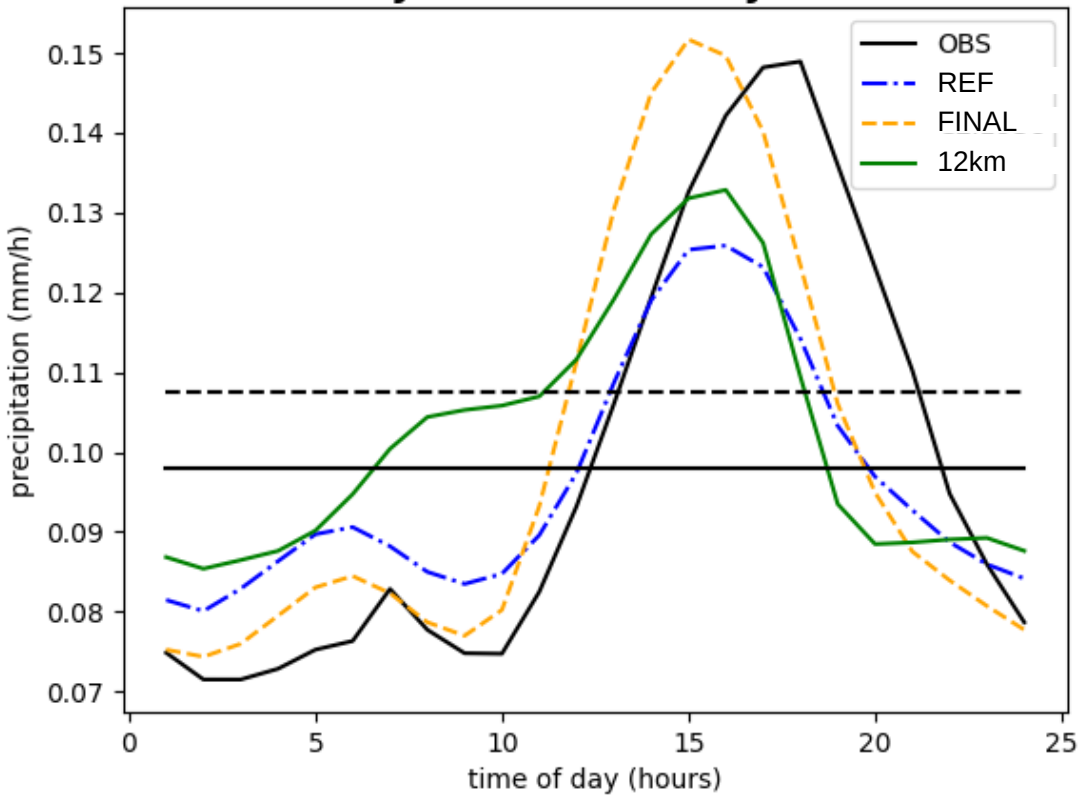


Comparison of final configurations

mean diurnal cycle, Germany, 2002-2003 JJA

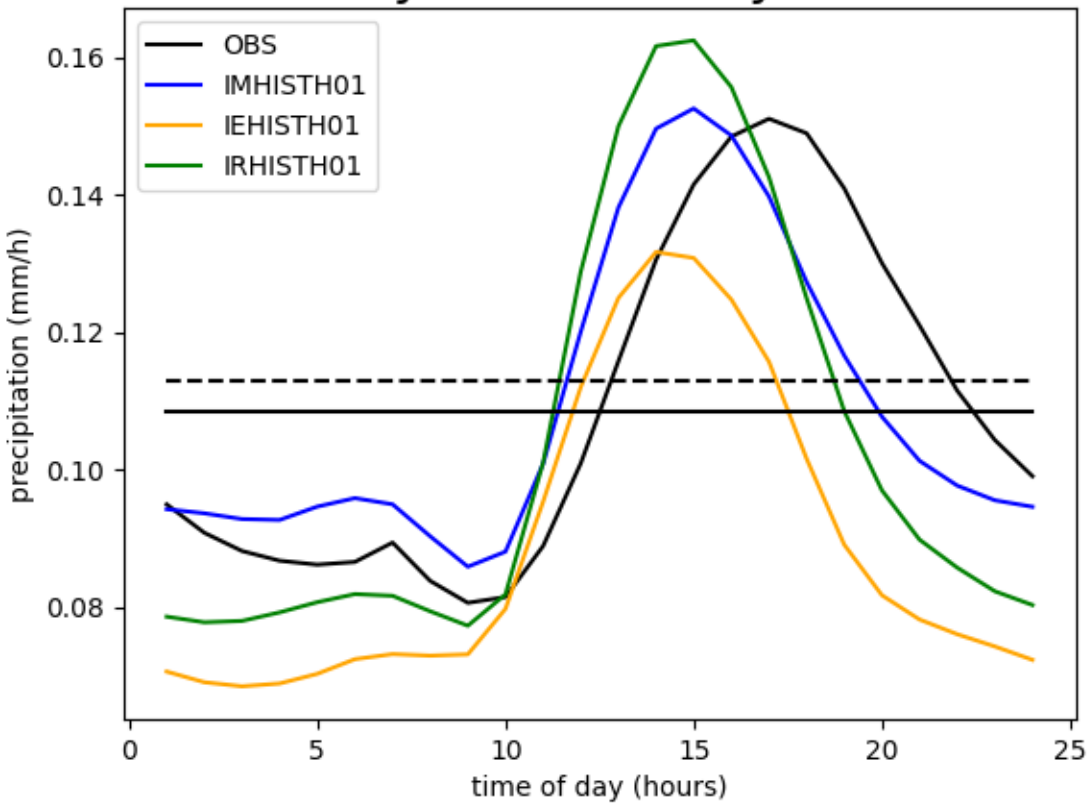


mean diurnal cycle, Germany, 2002-2005 JJA

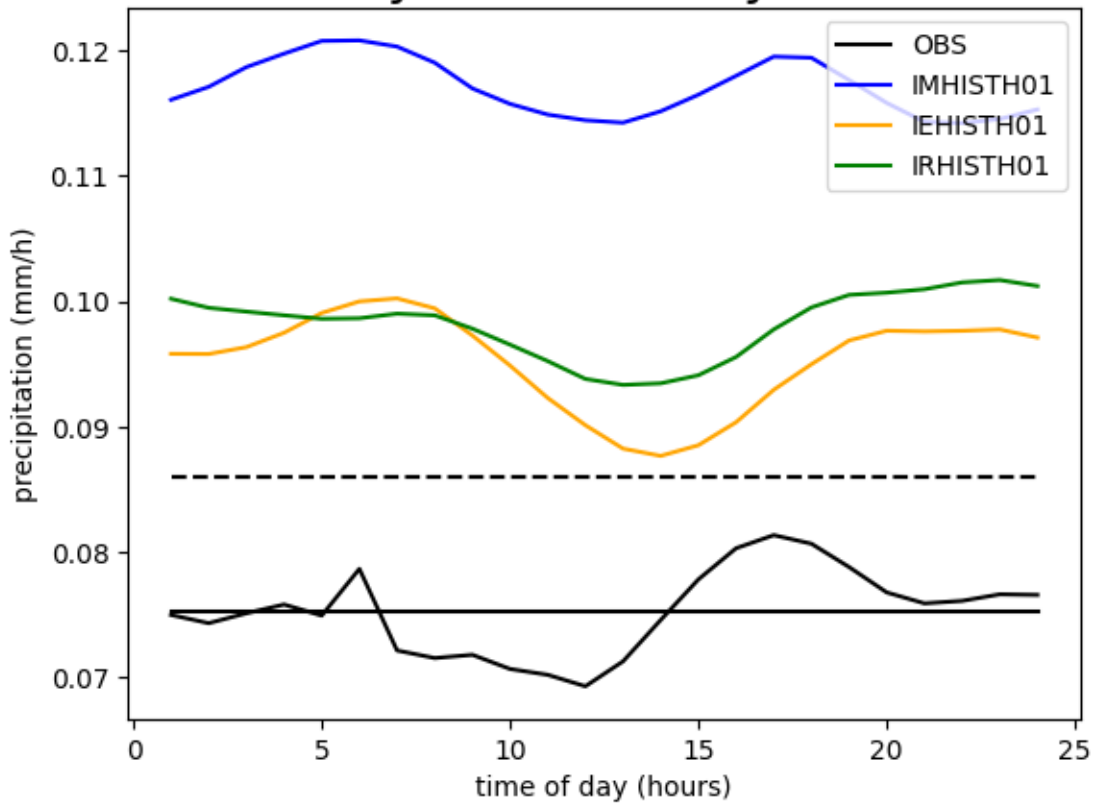


diurnal cycle in UDAG historicals

mean diurnal cycle, Germany, 2001-2014, JJA



mean diurnal cycle, Germany, 2001-2014, DJF



Summary

- Extreme precipitation
  - two-moment microphysics scheme and Cape-offset tuning improve all considered quality measures
  - Historical simulations reproduce high percentiles of extreme precipitation very well (except MIROC driven simulation which overestimates extreme precip)
- Diurnal cycle
  - some improvements over reference and 12km configuration; high sensitivity in summer; some regional differences but with similar findings; afternoon peak still too early in most cases
  - Historical simulations show quite large variability, also in winter

Conclusions

- Final configuration shows reasonable results, improved through the tuning
- two-moment microphysics scheme too computationally expensive + more tuning needed
  → cape-offset tuning with grayzone tuning chosen for final configuration / production